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Sugaya et al.

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(54) **FUEL INJECTION DEVICE**

(71) Applicant: **Hitachi Automotive Systems, Ltd.**, Hitachinaka (JP)

(72) Inventors: **Masashi Sugaya**, Hitachinaka (JP); **Takao Miyake**, Hitachinaka (JP); **Yasuo Namaizawa**, Hitachinaka (JP)

(73) Assignee: **HITACHI ASTEMO, LTD.**, Hitachinaka (JP)

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CPC F02M 61/04; F02M 61/20–205; F02M 2200/50
See application file for complete search history.

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Primary Examiner — Joseph A Greenlund
(74) *Attorney, Agent, or Firm* — Foley & Lardner LLP

(57) **ABSTRACT**

For a fuel injection device, a configuration to improve fuel sealability when a valve is closed is provided. Therefore, the fuel injection device includes: a valve body that opens and closes a fuel flow path; a movable iron core in which a fuel passage hole communicating an upstream side and a downstream side is formed, and that operates the valve body toward the upstream side; a biasing spring whose one end contacts the movable iron core, and that biases the movable iron core in a valve opening direction; and a regulating unit that regulates movement of the one end of the biasing spring, in which the shortest distance between the one end of the biasing spring and the fuel passage hole is larger than a radial travel distance of the one end until radial movement of the one end is regulated by the regulating unit.

5 Claims, 3 Drawing Sheets

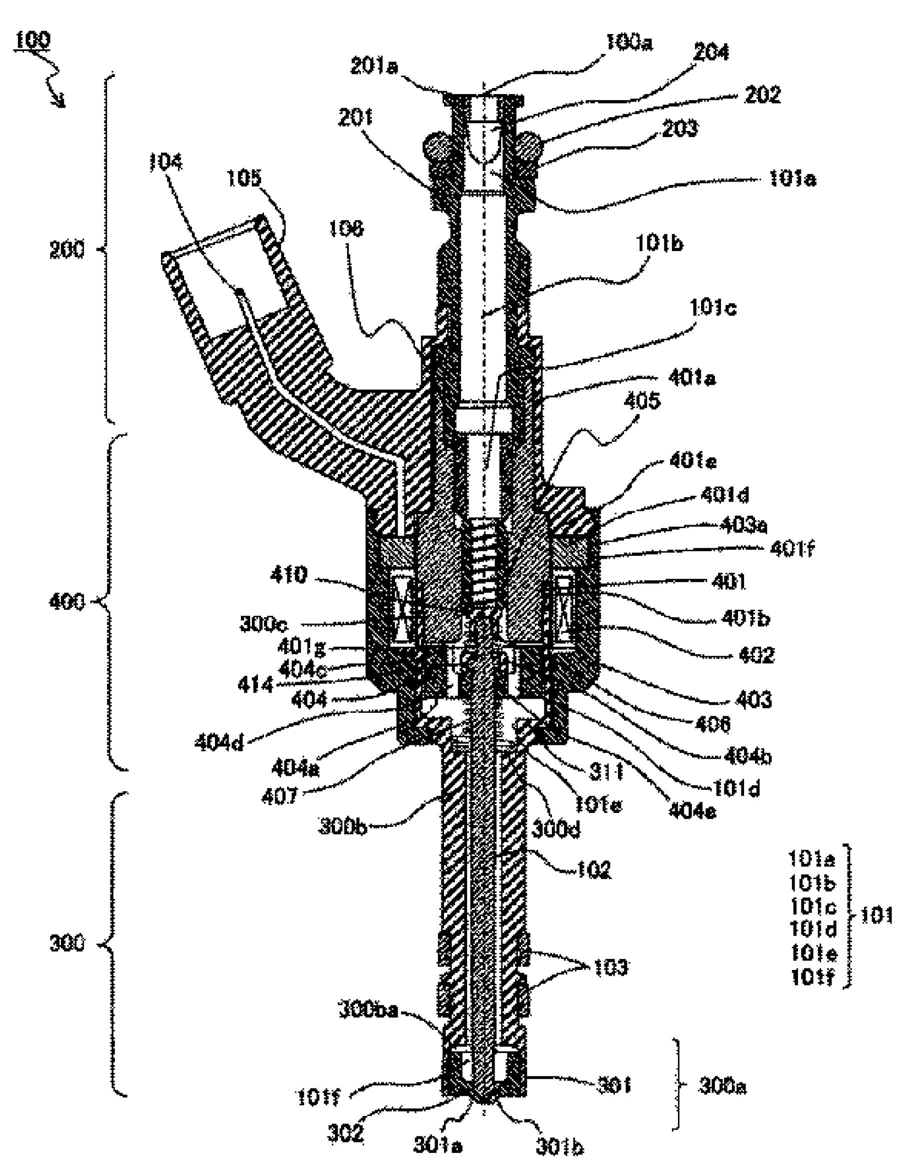

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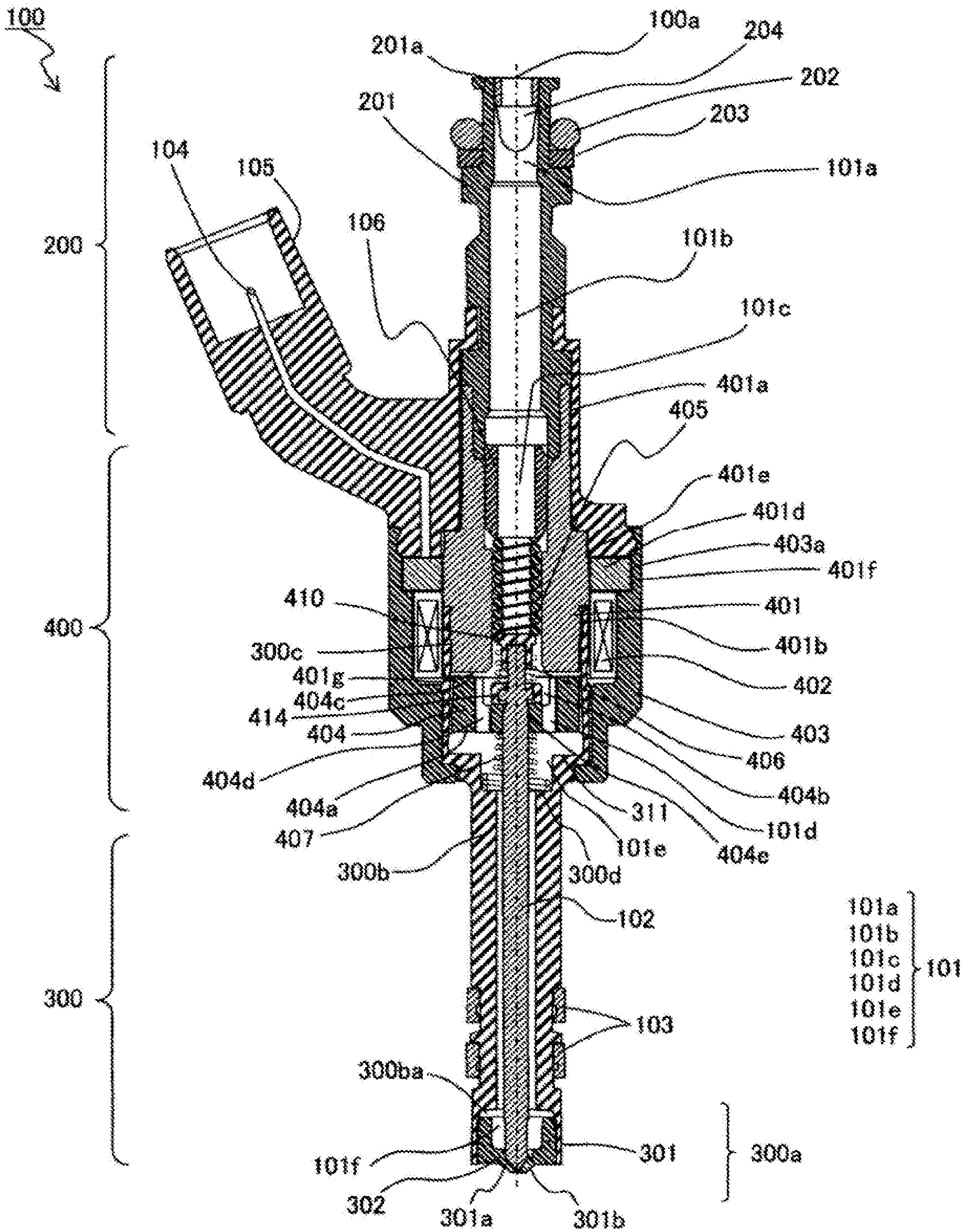
FIG. 1


100
100a
201a
204
202
201
203
101a
104
105
106
101b
200
101c
401a
405
401e
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403a
401f
410
401
401b
300c
402
401g
404c
414
403
404
406
404d
404b
404a
311
101d
407
101e
404e
300b
300d
102
101a
101b
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301
300a
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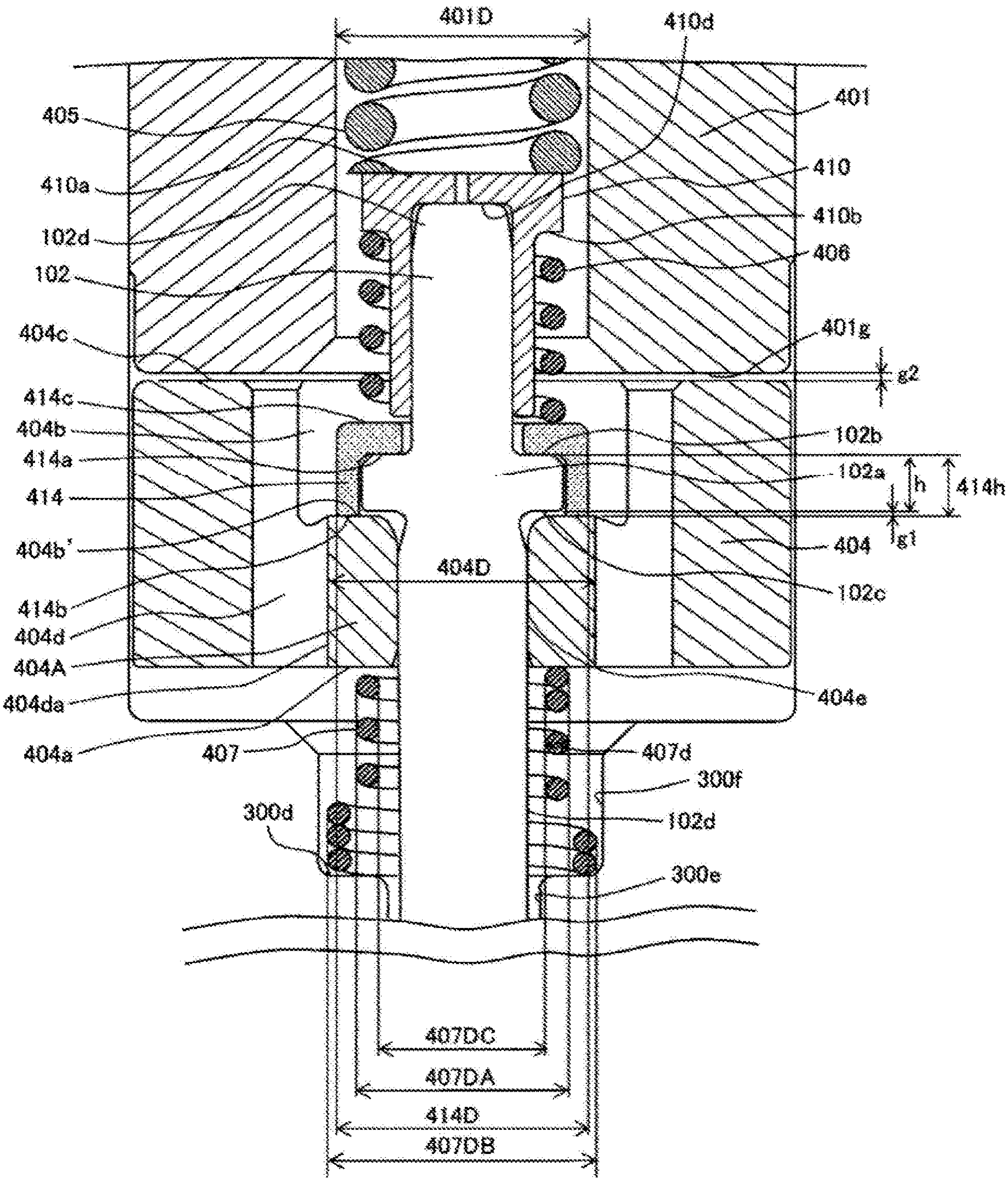
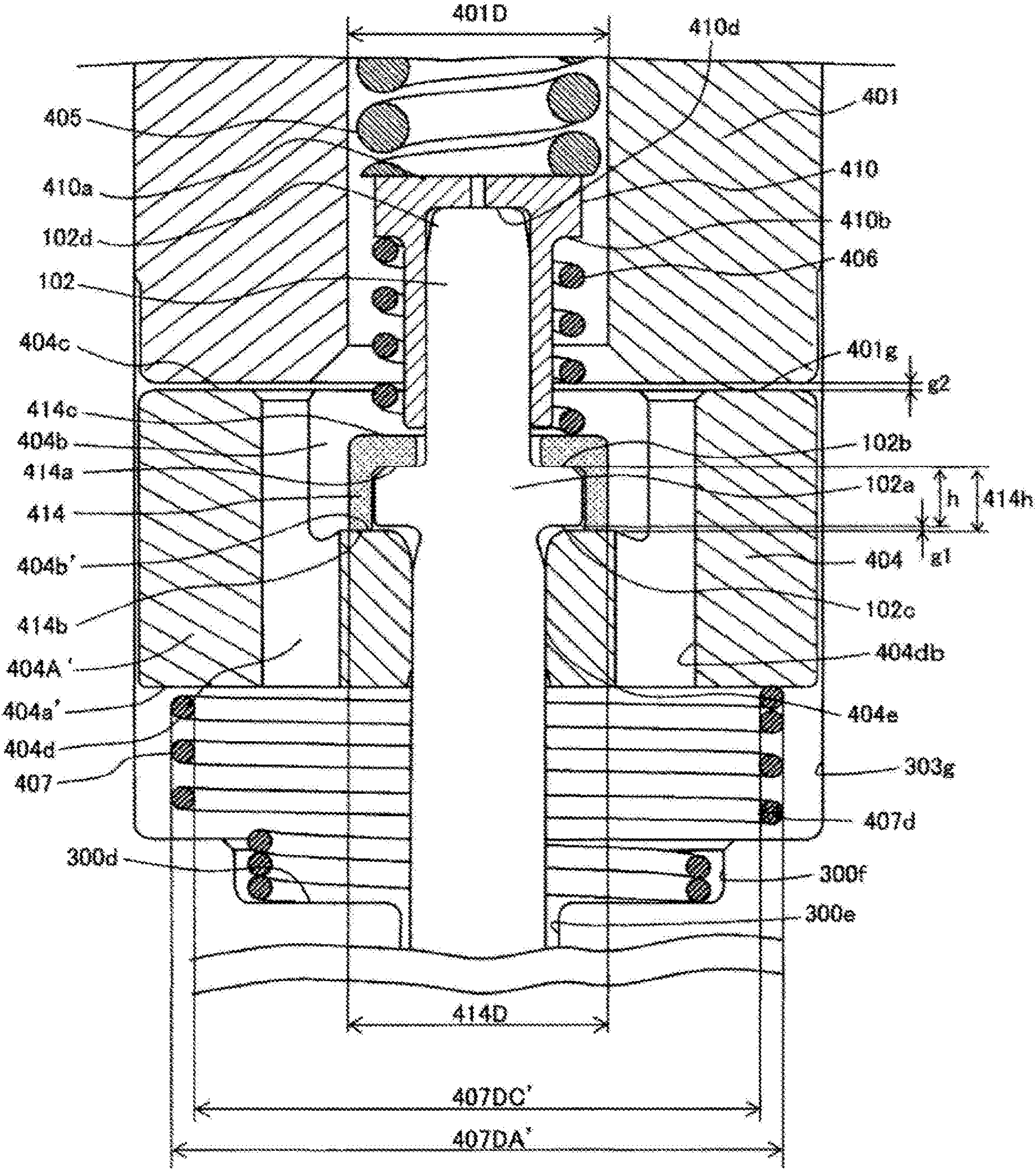
302
301a
301b

FIG. 2



401D
410d
401
405
410a
410
410b
102d
406
102
404c
401g
g2
414c
404b
102b
414a
102a
h
414h
414
g1
404b'
404
404D
102c
414b
404d
404A
404da
404e
404a
407
407d
300f
300d
102d
300e
407DC
407DA
414D
407DB

FIG. 3


401D
410d
401
405
410
410a
410b
102d
406
102
404c
401g
g2
414c
404b
102b
414a
102a
h
414h
414
g1
404b'
404
414b
102c
404A'
404db
404a'
404e
404d
407
303g
407d
300d
300f
300e
414D
407DC'
407DA'

FUEL INJECTION DEVICE

TECHNICAL FIELD

The present invention relates to a fuel injection device that is used in an internal combustion engine in order to mainly inject fuel.

BACKGROUND ART

As a background art of the present technical field, there is JP 2017-14921 A. In this publication, a fuel injection valve is described, in which: a magnetic path is formed such that a magnetic flux circulates around a fixed iron core, a movable iron core, a housing, and a large-diameter portion of a cylindrical member; the movable iron core is attracted toward the fixed iron core by a magnetic attraction force generated by the magnetic flux flowing between a lower end surface of the fixed iron core and an upper end surface of the movable iron core; in the center of the movable iron core, a recess recessed from the upper end surface toward the lower end surface is formed; in the upper end surface and a bottom surface of the recess, a fuel passage hole is formed as a fuel passage penetrating to the lower end surface in a direction along the central axis line; and an upper end portion of a second spring contacts a lower surface of the movable iron core and a lower end portion of the second spring contacts a stepped portion of a nozzle body, so that the movable iron core is biased upward.

CITATION LIST

Patent Literature

PTL 1: JP 2017-14921 A

SUMMARY OF INVENTION

Technical Problem

In the fuel injection valve described in the above JP 2017-14921 A, the lower end portion of the second spring that biases the movable iron core upward contacts the stepped portion of the nozzle body.

If this second spring is placed, for example, on a plane perpendicular to the spring axis direction with the spring axis direction of the second spring kept in the vertical direction, a winding end portion of the lower end portion of the second spring first contacts the plane. A step corresponding to the wire diameter of the second spring is usually created in the winding end portions of the upper end portion and lower end portion of the second spring. Therefore, if the second spring is placed on a plane perpendicular to the spring axis direction with the second spring kept in the vertical direction, the spring axis direction of the second spring is inclined from the vertical direction to a direction opposite to the winding end portion due to the step of the winding end portion of the lower end portion.

The fuel passage hole is formed in the movable iron core, and if the second spring is arranged to be inclined as described above, the winding end portion of the upper end portion of the second spring reaches the fuel passage hole in the lower end surface of the movable iron core, creating the fear that the winding end portion may be caught inside the fuel passage hole.

As the movable iron core moves in the vertical direction, the upper end portion of the second spring that contacts the

lower end surface of the movable iron core also and similarly moves in the vertical direction. The second spring changes its length by twisting itself while moving in the vertical direction.

As described above, if the upper end portion of the second spring is caught inside the fuel passage hole, the movable iron core is made eccentric by a force generated with the second spring twisting itself, so that uneven wear is caused in the sliding portion between the movable iron core and a valve body. Thereby, the movable iron core and the valve body are fixed together and moves integrally, so that an impact force on a valve seat, occurring when the valve is closed, increases. Also, there is the problem that bias contact may be caused in the fuel seal portion between the valve body and the valve seat by the uneven wear of the sliding portion, which deteriorates fuel sealability.

Therefore, an object of the present invention is to provide a configuration of a fuel injection device that improves fuel sealability when a valve is closed.

Solution to Problem

In order to solve the above problems, the present invention includes: a valve body that opens and closes a fuel flow path; a movable iron core in which a fuel passage hole for communicating an upstream side and a downstream side is formed, and that operates the valve body toward the upstream side; a biasing spring whose one end contacts the movable iron core, and that biases the movable iron core in a valve opening direction; and a regulating unit that regulates movement of the one end of the biasing spring, in which the shortest distance between the one end of the biasing spring and the fuel passage hole is larger than a radial travel distance of the one end until radial movement of the one end is regulated by the regulating unit.

Also, the present invention includes: a valve body that opens and closes a fuel flow path; a movable iron core that operates the valve body toward an upstream side; and a biasing spring that is formed such that its outer diameter is reduced from a lower end portion toward an upper end portion, and that biases the movable iron core toward the upstream side with the upper end portion contacting a lower end surface of the movable iron core.

Advantageous Effects of Invention

According to the present invention configured as described above, the stabilization of fuel sealability, when a valve is closed during long-term use of the fuel injection device, can be promoted.

Objects, configurations, and advantageous effects other than those described above will be clarified by the following description of embodiments.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a cross-sectional view illustrating a structure of a fuel injection device according to a first embodiment of the present invention, and is a longitudinal cross-sectional view illustrating a cut surface parallel to a central axis line **100***a*.

FIG. **2** is a view for explaining the vicinity of a movable iron core of the fuel injection device according to the first embodiment of the present invention, and is a cross-sectional view illustrating in an enlarged manner an electromagnetic drive unit of the fuel injection device illustrated in FIG. **1**.

FIG. **3** is a view for explaining the vicinity of a movable iron core of a fuel injection device according to a second embodiment of the present invention, and is a cross-sectional view illustrating in an enlarged manner a portion corresponding to the electromagnetic drive unit of the fuel injection device illustrated in FIG. **1**.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

First Embodiment

The configuration of a fuel injection device **100** according to a first embodiment of the present invention will be described with reference to FIGS. **1** and **2**. FIG. **1** is a cross-sectional view illustrating a structure of a fuel injection device according to the first embodiment of the present invention, and is a longitudinal cross-sectional view illustrating a cut surface parallel to a central axis line **100***a*. FIG. **2** is a cross-sectional view illustrating in an enlarged manner an electromagnetic drive unit **400** of the fuel injection device **100** illustrated in FIG. **1**. In FIG. **2**, hatching of a valve body **102** is omitted for easy viewing.

The fuel injection device **100** is configured to include: a fuel supply unit **200** that supplies fuel; a nozzle unit **300** at the tip portion of which a valve unit **300***a* for allowing and blocking the flow of the fuel is provided; and the electromagnetic drive unit **400** that drives the valve unit **300***a*.

In the present embodiment, the case, where the fuel injection device **100** is an electromagnetic fuel injection device for an internal combustion engine using gasoline as fuel, will be described as an example. Herein, the fuel supply unit **200**, the valve unit **300***a*, the nozzle unit **300**, and the electromagnetic drive unit **400** indicate corresponding portions of the cross section illustrated in FIG. **1**, which do not indicate a single part.

The fuel injection device **100** of the present embodiment is configured with: the fuel supply unit **200** provided on the upper end side in FIG. **1**; the nozzle unit **300** provided on the lower end side; and the electromagnetic drive unit **400** provided between the fuel supply unit **200** and the nozzle unit **300**. That is, the fuel supply unit **200**, the electromagnetic drive unit **400**, and the nozzle unit **300** are arranged in this order along the direction of the central axis line **100***a*.

The end portion of the fuel supply unit **200**, opposite to the nozzle unit **300**, is connected to a non-illustrated fuel pipe. The end portion of the nozzle unit **300**, opposite to the fuel supply unit **200**, is inserted into a mounting hole (insertion hole) formed in a non-illustrated intake pipe or a combustion chamber forming member (cylinder block, cylinder head, etc.) of the internal combustion engine.

The fuel injection device **100** receives supply of fuel from the fuel pipe through the fuel supply unit **200**, and injects the fuel from the tip portion of the nozzle unit **300** into the intake pipe or the combustion chamber. Inside the fuel injection device **100**, a fuel passage **101** (**101***a* to **101***f*) is formed such that the fuel flows substantially along the direction of the central axis line **100***a* of the fuel injection device **100** from the end portion (end portion opposite to the nozzle unit **300**) of the fuel supply unit **200** to the tip portion (end portion facing the intake pipe or the inside of the combustion chamber) of the nozzle unit **300**.

In the following description, of both end portions in the direction along the central axis line **100***a* of the fuel injection device **100**, the end portion or the end portion side of the fuel supply unit **200**, located on the opposite side to the nozzle unit **300**, is referred to as a base end portion or a base end portion side, while the end portion or the end portion side of the nozzle unit **300**, located on the opposite side to the fuel supply unit **200**, is referred to as a tip portion or a tip portion side. Additionally, each unit constituting the fuel injection device **100** will be described by attaching "up" or "down" based on the vertical direction in FIG. **1**. This is done for easy understanding of description, which does not limit the mounting form of the fuel injection device **100** on the internal combustion engine to this vertical direction.

(Configuration Description)

Hereinafter, the configurations of the fuel supply unit **200**, the electromagnetic drive unit **400**, and the nozzle unit **300** will be described in detail.

The fuel supply unit **200** includes a fuel pipe **201**. A fuel supply port **201***a* is provided at one end portion (upper end portion) of the fuel pipe **201**, and the fuel passage **101***a* is formed inside the fuel pipe **201** so as to penetrate in the direction along the central axis line **100***a*. The other end portion (lower end portion) of the fuel pipe **201** is joined to one end portion (upper end portion) of a fixed iron core **401**.

An O-ring **202** and a backup ring **203** are provided on the outer peripheral side of the upper end portion of the fuel pipe **201**.

The O-ring **202** functions as a seal for preventing fuel leakage when the fuel supply port **201***a* is attached to the fuel pipe. The backup ring **203** is for backing up the O-ring **202**. The backup ring **203** may be configured by stacking a plurality of ring-shaped members. A filter **204** is provided inside the fuel supply port **201***a* in order to filter foreign substances mixed in the fuel.

The nozzle unit **300** includes a nozzle body **300***b*, and the valve unit **300***a* is provided at the tip portion (lower end portion) of the nozzle body **300***b*. The nozzle body **300***b* is a hollow cylindrical body, and constitutes the fuel passage **101***f* on the upstream side of the valve unit **300***a*. A movable iron core receiving unit **311** is provided in the fuel passage **101***e* below the electromagnetic drive unit **400**. A tip seal **103**, for maintaining airtightness when the fuel injection device is mounted on the internal combustion engine, is provided on the outer peripheral surface of the tip portion of the nozzle body **300***b*.

The valve unit **300***a* includes an injection hole forming member **301**, a guide unit **302**, and the valve body **102**.

The injection hole forming member **301** is configured to include a valve seat **301***a* that seals fuel by contacting the valve body **102**, and a fuel injection hole **301***b* from which fuel is injected. The injection hole forming member **301** is fixed by being inserted into a recess inner peripheral surface **300***ba* formed at the tip portion of the nozzle body **300***b*. In this case, the outer periphery of the tip surface of the injection hole forming member **301** and the inner periphery of the tip surface of the nozzle body **300***b* are welded together, whereby fuel is sealed.

The guide unit **302**: is located on the inner peripheral side of the injection hole forming member **301**; constitutes a guide surface on the tip portion side (lower end portion side) of the valve body **102**; and guides the travel of the valve body **102** in the direction along the central axis line **100***a* (valve opening and closing direction).

The electromagnetic drive unit **400** is configured to includes the fixed iron core **401**, a coil **402**, a housing **403**, a movable iron core **404**, an intermediate member **414**, a plunger cap **410**, a first spring member **405**, a third spring member **406**, and a second spring member **407**. The fixed iron core **401** is also referred to as a fixed core. The movable iron core **404** is also referred to as a movable core, a mover, or an armature.

The fixed iron core **401** has the fuel passage **101***c* at its center, and has a joint portion **401***a* where it is joined to the fuel pipe **201**. An outer peripheral surface **401***b* of the fixed iron core **401** is fitted and joined to a large-diameter portion **300***c* of the nozzle body **300***b*, and an outer peripheral surface **401***e* having a larger diameter than the outer peripheral surface **401***b* is fitted and joined to an outer peripheral side fixed iron core **401***d*. The coil **402** is wound around the outer peripheries of the fixed iron core **401** and the large-diameter portion **300***c* of the cylindrical member.

The housing **403** is provided to surround the outer peripheral side of the coil **402**, and constitutes the outer periphery of the fuel injection device **100**. An inner peripheral surface **403***a* on the upper end side of the housing **403** is connected to an outer peripheral surface **401***f* of the outer peripheral side fixed iron core **401***d*.

The movable iron core **404** is arranged on the side of a lower end surface **401***g* of the fixed iron core **401**. An upper end surface **404***c* of the movable iron core **404** faces, in a valve closed state, the lower end surface **401***g* of the fixed iron core **401** with a gap g**2** interposed therebetween (see FIG. **2**). Also, the outer peripheral surface of the movable iron core **404** faces the inner peripheral surface of the large-diameter portion **300***c* of the nozzle body **300***b* via a slight gap, and the movable iron core **404** is provided inside the large-diameter portion **300***c* of the cylindrical member so as to be movable in the direction along the central axis line **100***a*.

A magnetic path is formed such that a magnetic flux circulates around the fixed iron core **401**, the movable iron core **404**, the housing **403**, and the large-diameter portion **300***c* of the cylindrical member. The movable iron core **404** is attracted toward the fixed iron core **401** by a magnetic attraction force generated by the magnetic flux flowing between the lower end surface **401***g* of the fixed iron core **401** and the upper end surface **404***c* of the movable iron core **404**.

In the center of the movable iron core **404**, a recess **404***b* recessed from the upper end surface **404***c* toward a lower end surface **404***a* is formed. In the upper end surface **404***c* and a bottom surface **404***b*' (see FIG. **2**) of the recess **404***b*, a fuel passage hole **404***d* communicating the upstream side and the downstream side is formed as the fuel passage **101***d* penetrating to the lower end surface **404***a* in the direction along the central axis line **100***a*. Also, in the bottom surface **404***b*' of the recess **404***b*, a through hole **404***e*, penetrating to the lower end surface **404***a* in the direction along the central axis line **100***a*, is formed. The valve body **102** for opening and closing the fuel flow path is provided to pass through the through hole **404***e*, and the movable iron core **404** operates the valve body **102** toward the upstream side. The plunger cap **410** is fixed to the valve body **102** by fitting, and the valve body **102** has a large-diameter portion **102***a* (see FIG. **2**).

The intermediate member **414** is a cylindrical member having the recess **404***b* that is a step between the inner periphery and the outer periphery, and of the lower side surfaces, a surface **414***a* (see FIG. **2**) on the inner peripheral side is made contact an upper surface **102***b* (see FIG. **2**) of the large-diameter portion **102***a* of the valve body **102**, while of the lower side surfaces, a surface **414***b* on the outer peripheral side is made contact the bottom surface **404***b*' of the recess **404***b* of the movable iron core **404**.

A gap g**1** is provided between the lower surface **102***c* (see FIG. **2**) of the large-diameter portion **102***a* of the valve body **102** and the bottom surface **404***b*' of the recess **404***b* of the movable iron core **404** (see FIG. **2**). The length, obtained by subtracting a height h (see FIG. **2**) between the upper surface **102***b* and the lower surface **102***c* of the large-diameter portion **102***a* of the valve body **102** from a height **414***h* (see FIG. **2**) of the step of the recess of the intermediate member **414**, is the gap g**1** described above.

The upper end portion of the first spring member **405** contacts the lower end surface of a spring force adjusting member **106**, the lower end portion of the first spring member **405** contacts an upper spring receiver **410***a* (see FIG. **2**) of the plunger cap **410**, and the first spring member **405** biases the valve body **102** downward via the plunger cap **410**.

The upper end portion of the third spring member **406** contacts a lower spring receiver **410***b* (see FIG. **2**) of the plunger cap **410**,

- the lower end portion of the third spring member **406** contacts an upper surface **414***c* (see FIG. **2**) of the intermediate member **414**, and
- the third spring member **406** biases the intermediate member **414** in the valve closing direction.

The upper end portion of the second spring member **407** contacts the lower end surface **404***a* of the movable iron core **404**, the lower end portion of the second spring member **407** contacts the bottom surface **300***d* of the nozzle body **300***b*, and the second spring member **407** biases the movable iron core **404** in the valve opening direction.

That is, a solenoid valve (fuel injection device **100**) of the present embodiment includes: the first spring member **405** that biases the valve body **102** in the valve closing direction; third spring member **406** that is attached to the plunger cap **410** or the valve body **102** so as to bias the intermediate member **414** in a direction in which a preliminary stroke gap (g**1**) is increased; and the second spring member **407** that biases the movable iron core **404** in the valve opening direction, in which the spring force of the first spring member **405**> the spring force of the third spring member **406**> the spring force of the second spring member **407**. Thereby, the preliminary stroke gap (g**1**) is formed in the valve closed state.

The coil **402** is attached to the fixed iron core **401** and the outer periphery of the large-diameter portion **300***c* of the nozzle body **300***b*, a cylindrical member, in the state of being wound around a non-illustrated bobbin, and a resin material is molded therearound. With the resin material used in the molding, a connector **105** having a terminal **104** drawn out of the coil **402** is integrally formed.

Herein, the fuel injection device **100** of the present embodiment includes: the valve body **102** that opens and closes the fuel flow path; and the movable iron core **404** that operates the valve body **102** toward the upstream side (valve opening direction). And, the second spring member **407** is formed such that its outer diameter is reduced from the lower end portion toward the upper end portion, and the upper end surface of the second spring member **407** contacts the lower end surface **404***a* of the movable iron core **404**, as illustrated in FIG. **2**, whereby the movable iron core **404** is biased toward the upstream side.

With the configuration of the present embodiment, the upper end portion of the second spring member **407** is located radially inward with respect to the fuel passage hole **404***d* of the movable iron core **404**, whereby the upper end portion of the second spring member **407** can be prevented from overlapping the fuel passage hole **404***d* of the movable iron core **404**, so that the upper end portion can be prevented from being caught by the fuel passage hole **404***d*. Thereby, the upper end portion of the second spring member **407** does not overlap the lower surface of the fuel passage hole **404***d* even if the second spring member **407** is arranged such that its spring axis direction is inclined from the vertical direction to the direction opposite to the winding end portion, and hence the movable iron core **404** can be suppressed from being eccentric as before. Therefore, uneven wear of the sliding portion between the movable iron core **404** and the valve body **102** can be suppressed, and as a result, fuel sealability can be suppressed from deteriorating.

The fuel passage hole **404***d* communicating the upstream side and the downstream side is formed in the movable iron core **404**, and the upper end portion of the second spring member **407** contacts the radial inside of the fuel passage hole **404***d*. More specifically, the upper end portion of the second spring member **407** contacts the lower end surface **404***a* of an inner diameter portion **404**A (see FIG. **2**) of the movable iron core **404**, the inner diameter portion **404**A being located radially inward with respect to the fuel passage hole **404***d*. In this case, the biasing spring (second spring member **407**) is configured such that an outer diameter portion **407**DA (see FIG. **2**) of the upper end portion contacts at a position corresponding to the radial center of the inner diameter portion **404**A of the movable iron core **404** (center position of the lower end surface **404***a* between the innermost peripheral position and the outermost peripheral position of the lower end surface **404***a*). With this configuration, the upper end portion of the second spring member **407** can be surely prevented from overlapping the fuel passage hole **404***d* of the movable iron core **404**, so that the upper end portion can be prevented from being caught by the fuel passage hole **404***d*.

The lower end portion of the second spring member **407** holds the valve body **102** on the inner peripheral side, and contacts the bottom surface **300***d* of a stepped portion **300***f* (see FIG. **2**) of the nozzle body **300***b*. That is, the fuel injection device **100** of the present embodiment holds the valve body **102** on the inner peripheral side, and includes a holding member (nozzle body **300***b*) having the stepped portion **300***f* that holds the biasing spring (second spring member **407**) on the inner peripheral side, whereby the lower end portion of the biasing spring (second spring member **407**) is brought into contact with and supported by the bottom surface **300***d* of the stepped portion **300***f*. Further, the biasing spring (second spring member **407**) is configured such that an outer diameter portion **407**DB (see FIG. **2**) of the lower end portion contacts the bottom surface **300***d* of the stepped portion **300***f* of the holding member (nozzle body **300***b*) at a position corresponding to the inner diameter portion **404**A of the movable iron core **404**. That is, the lower end of the second spring member **407** is configured not to fall into a small inner diameter **300***e* (see FIG. **2**) of the nozzle body **300***b* and the outer diameter portion **407**DB of the lower end portion of the second spring member **407** is not made bigger than necessary, which reduce the processing amount of the nozzle body **300***b* and the material that constitutes the second spring member **407**. Similarly, by not making the outer diameter portion **407**DB of the lower end portion of the second spring member **407** bigger than necessary, the difference between the outer diameter of the outer diameter portion **407**DB of the lower end portion and the outer diameter of the outer diameter portion **407**DA of the upper end portion of the second spring member **407** is reduced, and hence a variation of load generated in the range where the diameters of the upper end portion and the lower end portion are switched to each other can be reduced, and as a result, a variation of load in the second spring member **407** can be reduced.

Again, there is provided a biasing spring (second spring member **407**) by which the shortest distance between the upper end portion of the second spring member **407** and an inner diameter **404**D of the fuel passage hole of the movable iron core **404** is formed to be larger than a radial travel distance of the upper end portion of the second spring member **407** until radial movement of the upper end portion is regulated by the regulating unit. When the upper end portion of the biasing spring (second spring member **407**) is located radially inside the fuel passage hole **404***d*, the regulating unit is an outer peripheral portion **102***d* (see FIG. **2**) of the valve body **102**, and the biasing spring (second spring member **407**) is formed such that the shortest distance between the outer diameter portion **407**DA of the upper end portion of the second spring member **407** and the innermost peripheral portion **404***da* of the exit surface of the fuel passage hole **404***d* is larger than the radial travel distance between an inner peripheral portion **407**DC (see FIG. **2**) of the upper end portion of the second spring member **407** and the outer peripheral portion **102***d* of the valve body **102**. Further, the biasing spring is formed such that when the central axis of the biasing spring (second spring member **407**) and the central axis of the valve body **102** are on the same axis line and when the upper end portion of the second spring member **407** moves radially, the shortest distance between the upper end portion of the second spring member **407** and the inner diameter **404**D of the fuel passage hole of the movable iron core **404** is larger than the radial travel distance of the second spring member **407**. Further, with the fuel injection device **100** of the present embodiment, the biasing spring (second spring member **407**) is formed such that its outer diameter is reduced from its lower end portion toward its upper end portion.

With the configuration of the present embodiment, the upper end portion of the second spring member **407** is located radially inward with respect to the fuel passage hole **404***d* of the movable iron core **404**, whereby the upper end portion of the second spring member **407** can be prevented from overlapping the fuel passage hole **404***d* of the movable iron core **404**, so that the upper end portion can be prevented from being caught by the fuel passage hole **404***d*. Thereby, the upper end portion of the second spring member **407** does not overlap the lower surface of the fuel passage hole **404***d* even if the second spring member **407** is arranged such that its spring axis direction is inclined from the vertical direction toward a direction going to the portion opposite to the winding end portion, and hence the movable iron core **404** can be suppressed from being eccentric. Therefore, uneven wear of the sliding portion between the movable iron core **404** and the valve body **102** can be suppressed, and as a result, fuel sealability can be suppressed from deteriorating.

Further, the biasing spring (second spring member **407**) is formed such that the axial length of a small-diameter portion (upper end portion), having an outer diameter smaller than the outer diameter of the stepped portion (lower end portion) having the largest outer diameter, is larger than the axial length of the stepped portion. That is, in the fuel injection device **100** of the present embodiment, the second spring member **407** is formed such that the axial length of the outer diameter portion **407**DA of the upper end portion is larger than the axial length of the outer diameter portion **407**DB of the lower end portion. Thereby, the material of the spring (second spring member **407**) can be reduced. Further, in manufacturing, the outer diameter portion **407**DA of the upper end portion can be easily fixed in the assembly process of the second spring member **407** in which the outer diameter portion **407**DA is fixed and transported.

(Operation Description)

Next, the operation of the fuel injection device **100** according to the present embodiment and features of the present invention will be described. These will be mainly described with reference to FIG. **2** that is an enlarged view of the electromagnetic drive unit **400**.

(Valve Closed State Definition, Gap Description)

In a valve closed state in which the coil **402** is not powered, the valve body **102** contacts the valve seat **301***a* and is closed by a force obtained by subtracting the biasing force of the second spring member **407** from the biasing forces of the first spring member **405** and the third spring member **406** that bias the valve body **102** in the valve closing direction. This state is referred to as a valve-closed stationary state. In this case, the movable iron core **404** contacts the surface **414***b* on the outer peripheral side of the intermediate member **414**, and is arranged at a valve closed position. In the valve closed state in the fuel injection device **100** of the present embodiment, a gap that is related to a valve opening operation and to a movable part is configured as follows. The gap g**1** is provided between the bottom surface **404***b*' of the recess **404***b* of the movable iron core **404** and the lower surface **102***c* of the large-diameter portion **102***a* of the valve body **102**.

(Operation after Powering on)

After the coil **402** is powered, a magnetomotive force is generated by an electromagnet including the fixed iron core **401**, the coil **402**, and the housing **403**. With this magnetomotive force, a magnetic flux flows, the magnetic flux circulating around a magnetic path including the fixed iron core **401**, the housing **403**, the large-diameter portion **300***c* of the nozzle body **300***b*, and the movable iron core **404** that are configured to surround the coil **402**. At this time, a magnetic attraction force acts between the upper end surface **404***c* of the movable iron core **404** and the lower end surface **401***g* of the fixed iron core **401**, so that the movable iron core **404** and the intermediate member **414** are displaced toward the fixed iron core **401**. Thereafter, the movable iron core **404** is displaced by g**1** at which it contacts the lower surface **102***c* of the large-diameter portion **102***a* of the valve body **102**. At this time, the valve body **102** does not move.

Thereafter, when the movable iron core **404** contacts the lower surface **102***c* of the large-diameter portion **102***a* of the valve body **102**, the valve body **102** receives an impact force from the movable iron core **404** and is pulled up, so that the valve body **102** moves away from the valve seat **301***a*. Thereby, a gap is generated between the valve body **102** and the valve seat **301***a*, and the fuel injection hole **301***b*, a fuel passage, is opened. Since the valve body **102** starts opening on receiving the impact force from the movable iron core **404**, the rise of the valve body **102** becomes steep. At this time, the movable iron core **404** and the intermediate member **414** operate in the same manner as the valve body **102**.

Thereafter, when the valve body **102** is displaced by g**2** and the upper end surface **404***c* of the movable iron core **404** contacts the lower end surface **401***g* of the fixed iron core **401**, the intermediate member **414** is displaced upward, and the movable iron core **404** is displaced downward to contact again and then move away again; and the valve body **102** is displaced upward and the movable iron core **404** is displaced downward, and thereafter the displacement of the valve body **102** is stabilized to g**2**.

(Action, Effect)

In the present embodiment, the intermediate member **414** is provided below the third spring member **406** that generates a spring force on the movable iron core **404** and the valve body **102**, the intermediate member **414** being arranged to contact the bottom surface **404***b*' of the recess **404***b* of the movable iron core **404** and the upper surface **102***b* of the large-diameter portion **102***a* of the valve body **102**. Therefore, when the movable iron core **404**, the valve body **102**, and the intermediate member **414** perform a valve opening operation and the movable iron core **404** collides with the fixed iron core **401**, the movable iron core **404** moves in the valve closing direction, while the intermediate member **414** and the valve body **102** continue to move in the valve opening direction. In this state, no spring force acting between the movable iron core **404** and the valve body **102** is generated, so that a state in which a spring force is separated is created. Therefore, a spring force that changes with the movement of the movable iron core **404** is not transmitted to the valve body **102**, and conversely a spring force that changes with the movement of the valve body **102** is not transmitted to the movable iron core **404**, so that the two independently vibrate with collision. Also, when the two collide with each other again, the movable iron core **404** bounces again in the valve closing direction and the valve body **102** bounces again in the valve opening direction, but the two do not give and receive a force and move without acting spring forces that change with the movement of them, and the forces held by the valve body **102** and the movable iron core **404** are small. Therefore, the bounce of the movable parts converses faster than in the case where spring forces that change with the movements of each other act. With this effect, a fuel injection amount can be stabilized.

Further, in the valve closed state, the gap g**1** by which the movable iron core **404** is displaced is constituted by the difference between the height **414***h* of the step of the recess of the intermediate member **414** and the height h of the large-diameter portion **102***a* (height h between the upper surface **102***b* and the lower surface **102***c* of the large-diameter portion **102***a*) of the valve body **102**, that is, the gap g**1** is determined by the dimensions of parts; and hence adjustment in the assembly process is not required, so that the assembly process can be simplified.

When the power supply to the coil **402** is cut off, the magnetic force starts to disappear, and the valve is closed by the biasing force of the spring in the valve closing direction. After the displacement of the valve body **102** becomes 0, the valve body **102** contacts the valve seat **301***a*, and the valve is completely closed. Since the intermediate member **414** contacts the upper surface **102***b* of the large-diameter portion **102***a* of the valve body **102**, the displacement does not become smaller than 0.

On the other hand, the movable iron core **404** is further displaced in the valve closing direction even after the displacement of the intermediate member **414** becomes 0. After the movable iron core **404** is most displaced in the valve closing direction, it is displaced in the valve opening direction by the second spring member **407** such that the displacement becomes 0 again. The displacement becomes 0 again, and the movable iron core **404** collides with the intermediate member **414**.

In the configuration of the present embodiment, the outer diameter **414**D of the intermediate member **414** is made smaller than the inner diameter **401**D of the fixed iron core **401**. Therefore, in assembling the fuel injection device **100**, the plunger cap **410**, the valve body **102**, the third spring member **406**, and the intermediate member **414** can be integrated into one piece in advance and can be incorporated into the fuel injection device **100** after the gap g**1** is determined by the height **414***h* of the step of the recess of the intermediate member **414** and the height h of the large-diameter portion **102***a* of the valve body **102**, and in a state in which the spring force adjusting member **106** and the first spring member **405** are not inserted; and hence the gap g**1** can be stably managed while the assembly is made easy. In the present embodiment, the outer diameter **414**D of the intermediate member **414** is set to be smaller than the inner diameter **401**D of the fixed iron core **401**, but it is only required that the outermost diameter of a member to be assembled in advance is made smaller, and if the outermost diameter of the plunger cap **410** is larger than the outer diameter **414**D of the intermediate member **414**, the outermost diameter of the plunger cap **410** may be smaller than the inner diameter **401**D of the fixed iron core **401**.

In the present invention, even if the movable iron core **404** has the same surface as the upper end surface **404***c* without the recess **404***b*, the same action effects as the present invention can be obtained. The reasons why the recess **404***b* of the movable iron core **404** is provided are that: the intermediate member **414** can be arranged on the further lower side; the length in the valve opening and closing direction of the valve body **102** can be shortened; and the valve body **102** that is accurate can be configured.

Second Embodiment

Next, the configuration of a fuel injection device according to a second embodiment of the present invention will be described with reference to FIG. **3**.

FIG. **3** is a view for explaining the vicinity of a movable iron core of a fuel injection device according to a second embodiment of the present invention, and is a cross-sectional view illustrating in an enlarged manner a portion corresponding to the electromagnetic drive unit of the fuel injection device illustrated in FIG. **1**. In FIG. **3**, the parts having the same numbers as those in the first embodiment have no difference in configurations and action effects, and hence description thereof will be omitted. In FIG. **3**, hatching of the valve body **102** is omitted for easy viewing, similarly to FIG. **2**.

In the present embodiment, a second spring member **407** is formed such that its outer diameter is increased from the lower end portion toward the upper end portion. In the present embodiment, a nozzle body **303***b* having the shape illustrated in FIG. **3** is used instead of the nozzle body **300***b* of the first embodiment. When the upper end portion of the biasing spring (second spring member **407**) is located radially outside the fuel passage hole **404***d*, the regulating unit is an inner peripheral portion **303***g* of the nozzle body **303***b*, and the biasing spring (second spring member **407**) is formed such that the shortest distance between an inner peripheral portion **407**DC' of the upper end portion of the second spring member **407** and an outermost peripheral portion **404***db* of the exit surface of the fuel passage hole **404***d* is larger than the radial travel distance between an outer diameter portion **407**DA' of the upper end portion and the inner peripheral portion **303***g* of the nozzle body **303***b*.

With the configuration of the present embodiment, the upper end portion of the second spring member **407** is located radially outward with respect to the fuel passage hole **404***d* of the movable iron core **404**, whereby the upper end portion of the second spring member **407** can be prevented from overlapping the fuel passage hole **404***d* of the movable iron core **404**, so that the upper end portion can be prevented from being caught by the fuel passage hole **404***d*. Thereby, the upper end portion of the second spring member **407** does not overlap the lower surface of the fuel passage hole **404***d* even if the second spring member **407** is arranged such that its spring axis direction is inclined from the vertical direction toward a direction going to the portion opposite to the winding end portion, and hence the movable iron core **404** can be suppressed from being eccentric. Therefore, uneven wear of the sliding portion between the movable iron core **404** and the valve body **102** can be suppressed, and as a result, fuel sealability can be suppressed from deteriorating.

The present invention is not limited to the above embodiments, and various modifications are included.

For example, the above embodiments have been described in detail for easy understanding of the present invention, and they are not necessarily limited to those including all the configurations described above. Additionally, part of the configuration of a certain embodiment can be replaced with the configuration of another embodiment, or the configuration of a certain embodiment can be combined with the configuration of another embodiment. Additionally, part of the configuration of each embodiment can be added, deleted, or replaced for another configurations.

REFERENCE SIGNS LIST

100 fuel injection device
101 fuel passage
102 valve body
200 fuel supply unit
300 nozzle unit
301*a* valve seat
301*b* fuel injection hole
311 movable iron core receiving unit
400 electromagnetic drive unit
401 fixed iron core
402 coil
403 housing
404 movable iron core
405 first spring member
406 third spring member
407 second spring member
414 intermediate member

The invention claimed is:

1. A fuel injection device comprising:
   a valve body configured to open and close a fuel flow path;
   a movable iron core in which a fuel passage hole for communicating an upstream side and a downstream side is formed, and that is configured to operate the valve body toward the upstream side;
   a biasing spring whose upper end portion contacts the movable iron core, and that biases the movable iron core in a valve opening direction;
   a regulator configured to regulate movement of the upper end portion of the biasing spring; and
   a nozzle body, wherein
   a shortest radial distance between the upper end portion of the biasing spring and the fuel passage hole is larger than a radial travel distance of the upper end portion until radial movement of the upper end portion is regulated by the regulator,
   wherein the upper end portion has a smaller radial diameter than that of a lower end portion of the biasing spring below the upper end portion,
   the upper end portion is entirely radially inward from the fuel passage hole,

the upper end portion having a constant radial diameter, and the lower end portion having a constant radial diameter,

wherein the upper end portion and the lower end portion are arranged to form a gap between the lower end portion and an inner peripheral portion of the nozzle body, and to form a gap between the upper end portion and an outer peripheral portion of the valve body,

wherein the gap between the lower end portion of the biasing spring and the inner peripheral portion of the nozzle body is narrower than the gap between the upper end portion of the biasing spring and the outer peripheral portion of the valve body.

2. The fuel injection device according to claim **1**, wherein

when a central axis of the biasing spring and a central axis of the valve body are on the same axis line, the shortest radial distance between the upper end portion and the fuel passage hole is larger than the radial travel distance of the upper end portion.

3. The fuel injection device according to claim **1**, wherein:

the regulator is the outer peripheral portion of the valve body; and

when the upper end portion of the biasing spring is located radially inward with respect to the fuel passage hole, the shortest radial distance between an outer peripheral portion of the upper end portion of the biasing spring and an innermost peripheral portion of the fuel passage hole is larger than the radial travel distance of the upper end portion of the biasing spring, the radial travel distance being between an inner peripheral portion of the upper end portion and the outer peripheral portion of the valve body.

4. The fuel injection device according to claim **1**, wherein an outer diameter of the biasing spring is reduced from the lower end portion of the biasing spring opposite to the upper end portion toward the upper end portion.

5. The fuel injection device according to claim **4**, wherein in the biasing spring, an axial length of the upper end portion is larger than an axial length of the upper lower end portion.

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